Load Hiding to Preserve Privacy from Smart Meter Measurements

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Smart Meters

Provide More information
More accurate forecasting
Fault detection
Increased information to consumers
Increased stability for renewables and energy storage

United States Smart Meter Use, 2014
Non-Invasive Load Monitoring (NILM)

Capable of Identifying Specific Appliances

Loss of privacy

Map activities and behaviors of homeowners
Previous Research

Battery-based Load Monitoring

Home Power Use

Battery

Power Read by Meter
Project Goal

Design a system to improve individual household privacy

Maintain the benefits provided by smart meters
Entropy is the measure of unpredictability of information

\[ H(X) = - \sum_{i=1}^{n} P(x_i) \log_2 P(x_i) \]

\[ H_{max}: \quad P(x_i) = \frac{1}{n} \]
Load Imitating

Add false loads in order to increase system entropy

Model of Television Power Demand

Model of Lighting Power Demand
Data
## Analyzed Loads

<table>
<thead>
<tr>
<th>Load</th>
<th>Power [W]</th>
<th>Duration [minute]</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>STD</td>
<td>Minimum</td>
</tr>
<tr>
<td>Additional</td>
<td>53.0</td>
<td>0.0</td>
<td>53.0</td>
</tr>
<tr>
<td>Computer</td>
<td>10.0</td>
<td>0.0</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td>246.5</td>
<td>7.8</td>
<td>230.0</td>
</tr>
<tr>
<td>Cooking</td>
<td>1233.0</td>
<td>39.4</td>
<td>1150.0</td>
</tr>
<tr>
<td>TV</td>
<td>20.0</td>
<td>0.0</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td>106.4</td>
<td>7.9</td>
<td>90.0</td>
</tr>
<tr>
<td>Washing</td>
<td>3260.7</td>
<td>428.5</td>
<td>2400.0</td>
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<tr>
<td></td>
<td>417.5</td>
<td>20.1</td>
<td>375.0</td>
</tr>
<tr>
<td>Lighting</td>
<td>13.9</td>
<td>7.4</td>
<td>11.0</td>
</tr>
<tr>
<td></td>
<td>29.0</td>
<td>0.0</td>
<td>29.0</td>
</tr>
<tr>
<td></td>
<td>61.3</td>
<td>31.5</td>
<td>40.0</td>
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<tr>
<td></td>
<td>8.0</td>
<td>0.0</td>
<td>8.0</td>
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<tr>
<td>Refrigerator</td>
<td>187.3</td>
<td>118.5</td>
<td>120.0</td>
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<tr>
<td>Freezer</td>
<td>134.8</td>
<td>78.4</td>
<td>120.0</td>
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<tr>
<td>Dishwasher</td>
<td>930.7</td>
<td>739.3</td>
<td>120.0</td>
</tr>
<tr>
<td>HVAC</td>
<td>317.8</td>
<td>0.0</td>
<td>317.8</td>
</tr>
</tbody>
</table>
Formula

\[ B(t) = \frac{1}{2n} \sum_{i=-n}^{n} A(t + i) - A(t) \]

when \( B(t) > 0 \) battery discharges
\( B(t) < 0 \) battery charges

Probability of Load Occurring = \( A(t) + B(t) \)
Results

Total Power Demand Comparison

- Power Demand (W)
- Time (hrs)

Imitation
Original
Results

![Graph showing entropy difference for various load types](image)

- **Load Type**: CFL, Computer, Cooking, Dishwasher, Dryer, Freezer, Halogen, HVAC, Incandescent, Linear Fluorescent, Refrigerator, TV, Washer
- **Comparisons**:
  - Original Entropy
  - Imitating Entropy
- **Entropy Values**:
  - Values range from 0 to 500

*Source: CURRENT*
Possible Further Work

Design to work with non-time based loads

Optimize with a battery

Test with more realistic data

Test against NILM
Acknowledgements

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Questions and Answers